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PROCESSING SOYBEANS FOR OIL AND MEAL

Soybeans vary considerably in color, size, and chemical composition. Variety, climate, and type and fertility of the soil on which they are grown affect the chemical composition of the bean. On a moisture-free basis, the oil content ranges from 14 to 24 percent with an average of 19.8; the protein content, from 30 to 50 percent with an average of 42.9; and the ash, from 3.5 to 6 percent. The varieties with yellow seed coats are processed on a much larger scale than the black, brown, and green varieties.

Soybeans are classed in Federal regulatory acts as a grain, and the U. S. Department of Agriculture administers an inspection service for assigning grade designations to soybean shipments which are sold by grade. According to the United States standards which have been established for soybeans, the requirements for the No. 2 or contract grade include a minimum test-weight of 54 pounds per Winchester bushel and a maximum limit of 14 percent moisture, 15 percent splits, 3 percent damage, 2 percent foreign material other than dockage, and 3 percent other colors. Soybeans are sold on the weight basis, prices being quoted on a 60-pound unit referred to as a bushel. Information concerning grading service for soybeans may be obtained from the Grain Products Branch, Office of Distribution, War Food Administration, U. S. Department of Agriculture, Washington 25, D. C. Responsibility for the wartime production of soybean oil and oil meal has been delegated to the Commodity Credit Corporation of the U. S. Department of Agriculture, with which soybean processors must now make a contract covering their operations.

A futures market for soybeans is provided on the Chicago Board of Trade, but its operation has been suspended as a result of wartime oilseed marketing restrictions. There is a futures market for soybean oil meal on the Memphis Merchants Exchange, and for soybean oil on the New York Produce Exchange.

Soybeans are shipped and stored in much the same manner as corn, wheat, and other grains. Clean, cool beans free from soil and mold may be stored safely for protracted periods provided the moisture content does not exceed 13 percent. If, however, there is evidence of heating or if the beans are moldy or excessively dirty, extensive damage may result on storing, even when the moisture content is considerably under 13 percent.

Hydraulic pressing, expeller or screw pressing, and solvent extraction are the three methods in general use for extracting oil from soybeans. All find application in this country. The 1942 crop yielded about 187 million and the 1943 crop about 196 million bushels of beans; and approximately 133 million bushels of the former were processed for oil

and meal. There are approximately 100 soybean mills in the United States, excluding about 200 cottonseed and other oilseed crushing mills which are crushing soybeans only temporarily or part of the time. The soybean processing industry, exclusive of these latter plants, has an installed capacity for about 130 million bushels of soybeans per year, of which 77 percent is represented by expellers and screw presses, 21 percent by solvent extractors, and 2 percent by hydraulic presses. That portion of the crop which is not processed for oil is consumed for seed, for feeding on the farm, for manufacturing soy flour, and for miscellaneous purposes.

Hydraulic pressing of soybeans is used almost exclusively by those plants which also process or have processed other oilseeds. Cottonseed and linseed pressing mills have been adapted satisfactorily to soybeans by modifying the milling and cooking equipment and the procedure. The beans are ground, rolled into thin flakes, cooked, formed into cakes which are wrapped with hair or wool mats, and pressed. The cakes are then trimmed, ground, and bagged. Under favorable conditions the cake as it comes from the press contains only about 5 percent oil.

When continuous presses are used, the beans are rather coarsely cracked and dried to a moisture content of 2 to 3 percent; they are then conveyed to a temperer mounted above the expeller where they are heated and where the moisture content is adjusted to a value which yields the best results under the pressing conditions employed. The hot, cracked beans are fed continuously into the expeller or screw press where they are compressed by means of a powerful rotating screw and forced through a cylinder which is composed of longitudinal steel bars spaced a few thousandths of an inch apart. The high temperature employed and the pressure developed in the process cause the oil to be squeezed out of the beans, and it escapes from the compressed material by flowing out through the slots between the bars. The material remaining is forced on through the cylinder and is discharged as irregularly shaped fragments containing 4.0 to 5.5 percent oil. It is cooled and ground to produce soybean oil meal. The crude oil is screened and then clarified by filtration before being sent to the refinery.

One ton of soybeans processed by either the hydraulic or expeller press yields approximately 300 pounds of oil and 1,600 pounds of cake, the 100 pounds of loss being due principally to moisture shrinkage. Continuous pressing is favored over hydraulic crushing because less hand labor is required. Subsequent treatment of the oil to obtain the grades offered to the various industries is essentially the same after both pressing processes.

In the solvent extraction of the oil as carried out in this country, the soybeans are cracked and adjusted to a moisture content of about 12 percent. They are then rolled into thin flakes and passed continuously through an extractor countercurrent to the flow of solvent which is usually a commercial grade of hexane. After the extracted flakes are discharged, they are freed from the entrained solvent which is returned to

the system. When the flakes are to be used as a source of industrial protein, this solvent removal should be effected with a minimum application of heat and in the absence of moisture in order to avoid denaturing the protein, that is, reducing its solubility. On the other hand, high temperatures are used to evaporate solvent from flakes which are destined for use in feeds, and the solvent-free meal is thereafter toasted, i.e., heated to a high temperature in the presence of considerable moisture, in order to impart to it a golden brown color, agreeable taste and odor, and enhanced nutritive value. When the extraction process is operated efficiently, the meal contains essentially no solvent and 1 percent or less of oil. The solvent is distilled from the oil and is returned to the extractor. With a proper installation and good supervision solvent losses should be kept under 0.75 percent of the weight of the beans extracted. The solvent extraction process is used widely in Europe, and is slowly but steadily growing in importance in the soybean industry in this country.

The meal produced in processing soybeans is of interest chiefly because of its protein content. Little attention has as yet been paid to its carbohydrate fraction which is distinguished by its very low content or complete absence of starch. The protein apparently consists largely of the globulin glycinin, together with smaller quantities of albumin-like legumelin. The principal amino acids found in glycinin, together with their approximate percentages, are as follows: Glutamic acid, 20 percent; aspartic acid, 3.7-15.0 percent; lysine, 1.8-9.0 percent; leucine, 8.45-10.00 percent; arginine, 3.3-8.0 percent; phenylalanine, 3.8-5.2 percent; and proline, 3.8-4.8 percent. Other amino acids are present in smaller quantities. Soybean meal finds its greatest use as a protein concentrate for the feeding of livestock and, although no official estimates are available, before the war probably over 95 percent of the soybean oil meal annually disappearing in trade was so utilized. It is being used in the food industries to an increasing extent, and the manufacture of soy flour and soy grits is playing an important role in the present war food program. The industrial utilization of soybean meal and protein is based primarily on their adhesive properties, with the plywood and wallpaper coating industries consuming the largest quantities. Soybean meal is also used in plastics, orchard sprays, and foundry core binders, and the refined protein is finding application in beater and tub sizing of paper, in sizing for silk hosiery, in water paints, in artificial fibers, and in leather dressings.

Soybean oil is a mixture of fatty acid glycerides and is classed as a semidrying oil, its iodine number ranging from 120 to 141. The composition of the fatty acid content of a typical soybean oil in percent is: Saturated acids, 15.2; oleic, 23.6; linoleic, 57.9; and linolenic, 3.3. The saturated acids are approximately two-thirds palmitic and one-third stearic. Fatty acids other than those listed are present in small amounts. The refined oil is utilized chiefly in edible products, such as vegetable shortenings, salad and cooking oils, and margarine. The crude oil is refined by suitable alkali treatment, bleached with activated carbon or

fuller's earth, and then hydrogenated for use in shortenings or margarine. The finished product is deodorized by being heated in a high vacuum while a current of steam is passed through it. The oil is also used in the manufacture of paints, enamels, varnishes, linoleum, oilcloth, soap, and printing inks. Special grades of oil refined by suitable methods for specific uses are produced by the larger refiners of soybean oil. Information concerning trading standards for soybean oil may be obtained from the National Soybean Processors Association, 3818 Board of Trade Building, Chicago 4, Illinois.

Phosphatides, composed chiefly of lecithin and cephalin, occur in soybeans and are found in quantities ranging from 0.4 to 2 percent in both solvent- and pressure-extracted oils. At present phosphatides are recovered chiefly from solvent-extracted oil by emulsifying them with water and oil and separating the emulsion from the oil in a centrifuge. The phosphatides thus obtained are dried at low temperatures and pressures to a brown mass which contains approximately 40 percent oil and less than 1 percent moisture. Soybean phosphatides find use as wetting agents and antioxidants, principally in the confectionery and food industries. When properly purified, commercial soybean phosphatides are of a light brown color and are almost completely free from pronounced beany odor. Should wide uses develop for soybean phosphatides, they could be obtained directly from the bean as well as from the expressed oil.

A large number of the growers of soybeans, and others interested in the industry, are associated in the American Soybean Association (Mrs. J. M. Strayer, Secretary, Hudson, Iowa).

No attempt will be made to furnish cost data for the installation and operation of different types of milling and processing equipment since these data, together with considerable related information, may be obtained from manufacturers of such equipment. In listing the names of the following companies it is to be understood that their products are not recommended over those of any others engaged in the same line of business; the names are furnished merely for the convenience and information of those interested.

Manufacturers of Soybean Processing Equipment

Continuous presses:

V. D. Anderson Company, Cleveland, Ohio
French Oil Mill Machinery Company, Piqua, Ohio

Hydraulic pressing equipment:

French Oil Mill Machinery Company, Piqua, Ohio
Davidson-Kennedy Company, Atlanta, Georgia
Buckeye Iron and Brass Works, Dayton, Ohio

Continuous countercurrent solvent extractors:
Blaw-Knox Company, Blawnox, Pennsylvania
French Oil Mill Machinery Company, Piqua, Ohio
Allis-Chalmers Manufacturing Company, Milwaukee, Wisconsin
Sieck and Drucker, Inc. (Hildebrandt system),
9 South Clinton Street, Chicago, Illinois
Detrex Corporation, 13005 Hillview Avenue, Detroit 27, Michigan
Read Machinery Company, York, Pennsylvania

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20. Continuous Solvent Extraction of Vegetable Oils. C. W. Bilbe. Mech. Engin., 63, 357-360 (1941) and Cotton and Cotton Oil Press, 42 (12) A-8 to A-12 (1941).

21. The Respiration and Storage Behavior of Soybeans. Paul E. Ramstad and W. F. Geddes. Minn. Agr. Expt. Sta. Tech. Bul. 156.

Description of Mills

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